The True Accuracy of Food Label Calorie Counts

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Abstract

Lead Member: [redacted]

Nowadays, the United States is a hyper-regulated society pertaining to the consumption of healthy foods due to increased obesity rates within the past decades. The United States Food and Drug Administration (FDA) is responsible for this food regulation. Within its domain lies the food label, which helps the consumer learn health information about food products. Millions of people base their entire diet around these food labels, without questioning its accuracy. The FDA has stated that they allow 20% error in these food labels, specifically regarding the Calorie count.

For this experiment, testing was done to determine exactly how accurate these food labels are, and if major food companies are using this margin of error in their favor to make food more profitable. Four different snack foods were tested in order to calculate the amount of Calories each of them contained. This was done using a standard bomb calorimeter (a device for determining heats of combustion by igniting a sample in a high oxygen pressure) that was calibrated using benzoic acid. The food samples were pressed into roughly one gram pellets and were detonated in a firing chamber inside of a bucket of water. The water temperature was then measured to determine the amount of energy in each pellet.

The results found that there was an underestimating of the Calorie counts of the four food items, showing a higher percentage of Calories ranging from 5% to 20%. This does not completely support the claim of company manipulation, but definitely establishes a trend of underreporting.

Figure 1: The Obesity Epidemic in America. Image from Google Images.

Introduction

Lead Member: [redacted]

Ever since the 1980's, obesity rates in the United States nearly tripled, staggering to an unprecedented 30% (Mitchell et al., 2011). This growth occurred at the same time with the rise of fast food chains, sugary sodas, and other unhealthy food products. An obesity crisis emerged, and it sparked a national attention on health which included aspects such as Michelle Obama's school lunch program, the information diffusion on the health effects of obesity, and, most relevantly, food labels.

Food labels are an important source of information about foods' compositions. Countless food products contain these labels, which can be found usually on the back of a food product. Namely, these food labels help understand the consumer the number of proteins, vitamins, sodium, sugar, fats, and Calories—between many nutrients—that a serving size of a particular food contains (Center for Food Safety and Applied Nutrition, 2000). These labels are known to have a healthy effect on many adults' eating habits, since most of them read food labels (Kreuter, 2018).

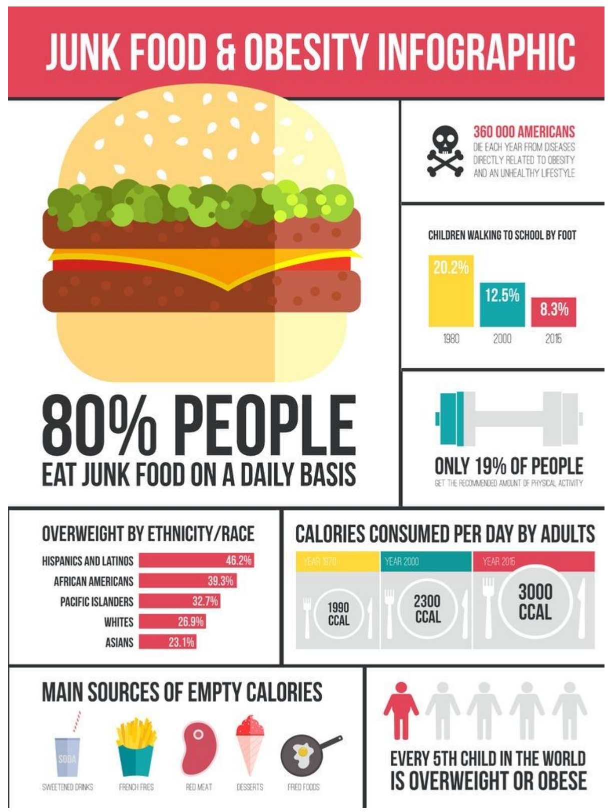

Figure 2: Junk Food and Obesity Infographic. Diagram from Google Images.

Of particular interest, the United States Food and Drug Administration (FDA) is responsible for regulating food labeling and safety for up to 80% of all the foods consumed in the United States. For example, some safety regulations that the FDA oversees include the sodium contents of food, the intake of folic acid by pregnant women, and the threats posed by inorganic arsenic, between many (Mayne & Spungen, 2017). Indeed, the FDA's control of essentially all of the safe food consumption within the United States makes it have a substantial effect on people's daily food choices (Mayne & Spungen, 2017).

Moreover, the FDA lays out the content, categories, and even the formatting of all food labels. Nonetheless, the accuracy of these labels has been under strict scrutiny in the past. For one thing, private companies are not the ones that are in control of their food labels, they only report the values. Explicitly, the FDA allows major food companies to measure their food products’ Calories and nutrients, under a very lenient policy. There can be as much as 20% of error—in either direction—for the label to meet the compliance criteria of the FDA (Urban et al., 2010). That is a huge gap for error. As an illustration, if a food label specifies 200 Calories per serving, the Calories could actually range between 160 and 240 Calories. This leaves a pretty wide margin for error in Calorie counts.

Beyond this, Calorie counts only need to be correct 95% of the time, giving even more leeway to error. This FDA rounding policy states that the Calorie count of a product on its food label must be to the nearest 5 Calorie increment if it has under 50 Calories, 10 Calorie increment if it has more than 50 Calories, and may be labeled as Calorie-free if it has less than 5 Calories. This alloted rounding error, combined with the 20% allowed error in individual scientific nutrition testing, could drastically misrepresent the Calorie count of a product.

All of this is more than enough wiggle room for food companies to get away with suboptimal ways to measure Calories. The method currently used, called the Atwater system, is over a hundred years old, although it has been numerically tweaked and modified (Novotney et al., 2012). This system looks at the individual components and assigns them a Calorie value—suchs as 4 Calories per gram for protein—to calculate total Calorie content. Recent studies have shown that the Atwater system is not just outdated, but inaccurate for certain food groups, like almonds (Novotney et al., 2012). Furthermore, analysis using bomb calorimetry to calculate Calorie counts is expensive and time-consuming (Evelyn Lau & Hui-Jen Goh, 2015). This would provide further cause for error, considering less rigorous testing results in less accurate results. Because of these lax accuracy demands and the outdated Atwater system, there is quite some reason to doubt Calorie counts.

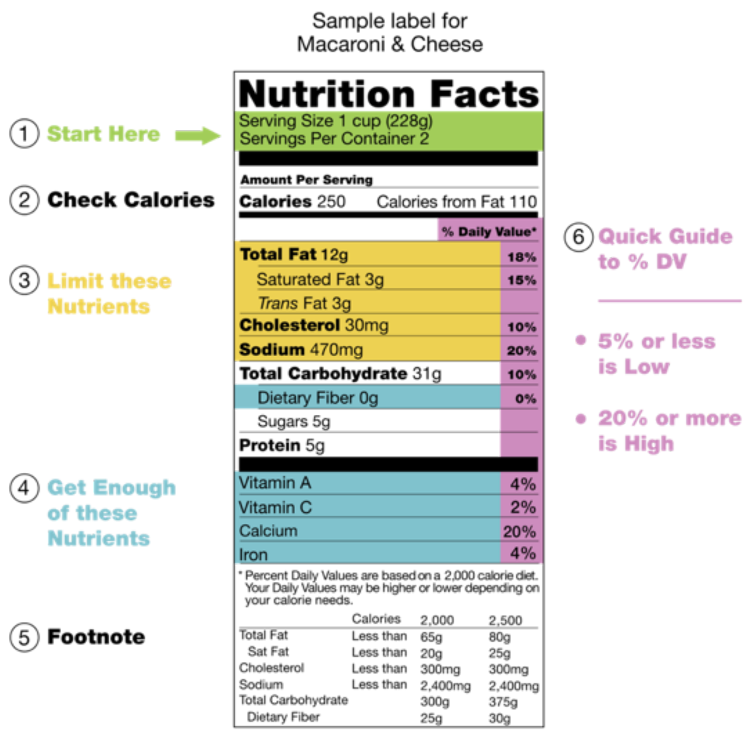

Figure 3: Sample Food Label with Instructions from the FDA. Diagram by Nutrition Facts Label Images for Download.

Moving forward, not only does this allows companies to get away with erroneous methods to measure Calories, but it also affects people who need to count the Calories they consume every day (Kiszko et al., 2014). Calorie intake is very important. Calories reflect on the energy a consumer gets from a serving of a particular food (Center for Food Safety and Applied Nutrition, 2000). Notably, statistics show that many people in the United States over consume Calorie-dense foods, ultimately resulting in obesity, diabetes, and heart disease, among many other diseases related to poor diets (Pomeranz & Brownell, 2008). With these nation-wide concerns, it is easy to realize the true significance that food labels have, and why it is very worrisome what food companies seem to be doing and how the FDA is the one allowing this manipulation of Calorie counts in the first place.

All things considered, certain products could be made more marketable if their Calorie count read a lower number, which ties in with this inquiry's motivation: revealing a possible, planned, manipulation of Calorie counts in either food brands or food subgroups (Kiszko et al., 2014). The results of this inquiry could disclose dishonest brands and make people more aware of the skeptical accuracy of food labels for them to make healthier choices.

To test this, our experiment analyzed a variety of food samples. We combusted these food samples in a bomb calorimeter to determine the energy released by the food, and from that the Calorie count can be determined. Our hypothesis is: if food labels are allowed a 20% error, then the food labels are manipulated in order to undervalue the Calorie count and make the products seem healthier and become more marketable. Other possible hypothesis include: if Calorie counts are reported by private food companies and the FDA allows a 20% margin error in them, then certain food brands will have more consistent inaccurate Calorie counts than other brands. Also, if we test a convenient variety of different types of foods, then certain food subgroups will have more accurate Calorie counts—such as diet cereals—than other food subgroups—such as regular cereals. Our null hypothesis states that food labels and Calorie counts are not manipulated by any private company despite the fact the fact the the FDA allows a 20% margin error.

Materials & Methods

Lead Member: [redacted]

To test the accuracy of Calorie counts, we combusted different food samples in a bomb calorimeter. Before this could be done, we needed to determine the specific heat of the calorimeter using benzoic acid. Benzoic acid is the best substance to use because it has a consistent combustion and heat capacity (Jessup, 1960). The heat capacity of benzoic acid is 6.314 Calories per gram, which we used in the following formula:

$$\text{Specific heat} = \frac{6.314\ Cal}{g\Delta T}$$

Using the process below, we combusted the benzoic acid and used the change in temperature, weight of combusted sample, and the heat capacity of benzoic acid, as seen in the previous formula, to obtain the specific heat of our bomb calorimeter. This was done four times and averaged to eliminate possible error.

Figure 4: Materials of a Bomb Calorimeter. Image by Santiago Gonzalez.

Next, we needed to find the change in temperature using our bomb calorimeter for each of our food samples' combustion. To make their combustion more consistent these foods need to be processed. The foods will need to be crushed into a fine powder and blended if they are not homogenous. Around one gram (no more than 2) of this powder is then pressed into pellets, which are then weighed and recorded. Before combusting the sample, the crucible must be cleaned. To combust the sample, place it into the crucible and measure 7 or 10 centimeters of firing wire and record the length. Run this wire in the holes of the two terminals and drape it close to the food sample. Squirt a few drops of water into the firing chamber. Screw the combustion chamber together tightly and pressurize it to 30 atmospheres, not exceeding 40. Fill the bucket with 2 liters of deionized water. Place the chamber into the water. If a constant stream of bubbles rise from the chamber, there is a leak. Do not ignite the sample, as this means there is a significant, possibly dangerous, problem with the calorimeter. If not, ensure the ignition box is not plugged in. Next, connect the ignition box leads to the terminals on the firing chamber in accordance with the length of firing wire used. Place the lid on the calorimeter, turn on the stirrer, and insert the thermometer probe. Wait until the temperature stops changing, then record this as the initial temperature. Plug in the ignition box and ignite the sample. Let the temperature settle out (it may spike up and then fall), and record the final temperature. Take out the firing chamber and open the purge valve before unscrewing the top. If the sample didn't fully combust, weigh the residue and subtract it from the pellet. Lastly, measure the length of the unburned wire and record it. Then, use the formula below to calculate the overall Calories of each sample.

To calculate the Calories per serving use the following formula:

$$\{((\frac{S * \Delta T}{Sample\ Weight}) - (W * (\frac{Cal\ of\ wire}{cm}))\} * \frac{g}{serving}$$

Where S is the specific heat of the calorimeter and W is the centimeters of wire burned. The length of wire burned is significant because the wire releases energy as heat. This will in turn increase the measured Calories, although by a small amount. Calories of wire per centimeter is usually provided with firing wire. After we gathered all of our data, we performed a 1-tailed T-test to see if our results were significant.

Results

Lead Member: [redacted]

Food product	Calories per serving	Serving size weight (g)	Pellet Weight (g)	Delta T (Cº)	Calories of wire	Measured Calories per Serving	Percent Error
Benzoic Acid 1st	N/A	N/A	1.00	2.7	0.01725	N/A	N/A
Benzoic Acid 2nd	N/A	N/A	1.00	2.66	0.0161	N/A	N/A
Benzoic Acid 3rd	N/A	N/A	1.00	2.61	0.0046	N/A	N/A
Benzoic Acid 4th	N/A	N/A	0.963	2.51	0.0115	N/A	N/A
Snickers 1st	250	55.3	1.00	1.84	0.0161	242.1	-3.14
Snickers 2nd	250	55.3	1.404	2.89	0.01265	271.2	8.47
Snickers 3rd	250	55.3	1.278	2.6	0.0161	267.8	7.13
Ritz 1st	80	16.6	1.00	3.06	0.0207	120.9	51.2
Ritz 2nd	80	16.6	0.967	2.14	0.0092	87.59	9.49
Ritz 3rd	80	16.6	1.46	3.1	0.0138	83.96	4.94
Ritz 4th	80	16.6	1.77	4.09	0.01265	91.42	14.3
All Bran 1st	120	37	1.00	1.6	0.0138	140.9	17.4
All Bran 2nd	120	37	1.28	2.1	0.01265	144.5	20.4
All Bran 3rd	120	37	1.09	1.84	0.0138	148.7	23.9
Pringles 1st	150	30.82	1.00	2.34	0.0184	178.3	18.9
Pringles 2nd	150	30.82	1.84	4.61	0.0138	184.0	22.7
Pringles 3rd	150	30.82	1.32	3.29	0.01495	183.0	22.0

Table 1: Inquiry Data.

All the food products that were tested appeared to have a different measured Calorie count than what the respective food label reported. As it can be seen from Table 1, for every test that was performed with the bomb calorimeter, the total length of the wire used, as well as the unburned part, was always recorded. The initial temperature of the water in the bomb calorimeter was recorded as well. Once the temperature peaks and stabilizes, the final temperature was recorded too. Using the data from testing benzoic acid, the specific heat of our calorimeter was found, which was needed to find the remaining Calories for each food. Once the Calorie count was found for each food, the Calorie count from the wire that was burned got removed. That way, each Calorie count is only representative of the food. At this point, the total Calories burned from each 1-2 gram sample was found. However, in order for us to compare it with what the corresponding food label reported, the results were multiplied with the serving size weight of each food. And finally, the percent error was found between the experimental Calorie count and the reported Calorie count. Table 2 yields the average percent error of each food label Calorie count.

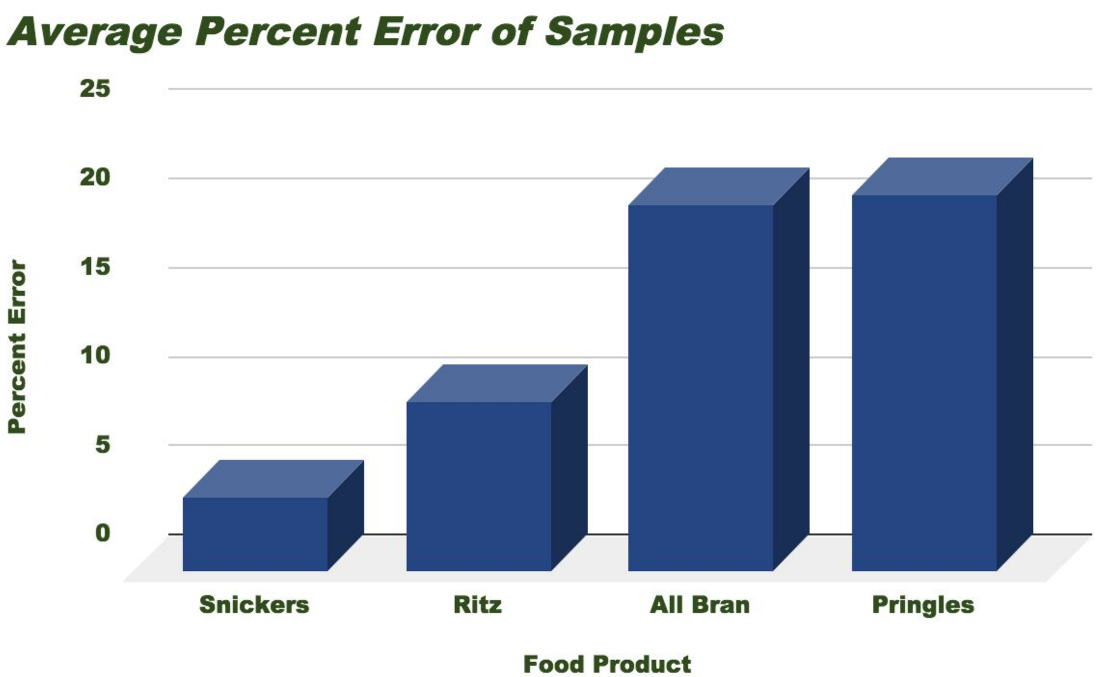

Table 2: Percent Error Graph

As shown in the tables and graph, significant error was recorded for each of the food groups, all of which was in the positive direction (meaning more Calories than expected). The Snickers bar sample had the smallest percent error with an average of only 4.15%. In one trial the Snickers bar sample had a percent error of -3.14%, meaning the reported Calorie count on the food label was actually greater than the calculated number of Calories. This was the only test trial that had a negative value. Moving on, the Ritz Crackers sample had the second lowest percent error with an average of 9.56%, excluding an outlier trial which will be elaborated on subsequently. Lastly, the All Bran and Pringles samples had the highest recorded percent errors, both of which were about twenty percent. Specifically, the All Bran had an average percent error of 20.57% and the Pringles had an average percent error of 21.18%. All together, the food samples had an average percent error of 13.87%.

Food	*Average Calorie Count Discrepancy*	*T-test P-value*
Snickers	***+4.15%***	***0.1876***
Ritz	***+9.56%***	***0.0354***
All Bran	***+20.57***	***0.0041***
Pringles	***+21.18%***	***0.0015***

Table 3: P-Value Table

To determine statistical significance, a 1-tailed, unequal variance T-test was used to analyze the 3 trials for each sample. A 1-tailed T-test was used over a more conservative 2-tailed, because all but one trial showed a measured Calorie count of over what was expected, so this is what our T-test measured the significance of. The T-test performed shows that if the standard P-value threshold of .05 is used, the Ritz, All Bran, and Pringles results are statistically significant.

In our experiment we encountered a few problems. Initially, we needed a more accurate thermometer to find more accurate changes in temperature. We at first were using a thermometer that could detect changes of only ±0.2 °C. This wasn't enough to detect a difference between our tests, but a better thermometer that detects changes of ±0.02 °C solved this issue. The most irritating issue was that, at times, the calorimeter simply wasn't combusting our food sample. A partial fix for this issue was to place a few drops of water into the firing chamber and to ensure the firing wire passes through the terminals, not just makes contact. These changes reduced the chance of failure, but it was never eliminated. Although this didn't affect our results, it did slow us down and limit the variety of food we tested. Lastly, in one of our trials with Ritz crackers, the calorimeter had a relatively large change in temperature. This amounted to a nearly 50% error from the label. This test was then repeated, and we found a 8.18% error from the label. We decided the first test was just an outlier in our results. A possible explanation for this discrepancy could be either leftover traces of benzoic acid contributing to the Calorie count, a thermometer malfunction, mis weighing of the sample, or something else unaccounted for.

Discussion

Lead Member: Al[redacted]

The FDA maintains the standards for almost all packaged food sold in stores (Mayne & Spungen, 2017). It maintains that the Calorie counts of food printed on a food label must not exceed the 20% error margin (Center for Food Safety and Applied Nutrition, 1998). For two of the four main samples, All Bran and Pringles, we measured discrepancies that hovered around the 20% limit set by the FDA. Even for the other two samples, we measured a Calorie count of about 5% higher for Snickers and 10% higher for Ritz in the positive direction. This indicates a fairly clear trend of overestimated Calories for each of these popular snack products. This data was also mimicked in a similar study done on snack foods where the Calorie counts on average were off by an average of about 4% (Jumpertz, 2012).

These results suggest an underreporting of Calorie counts, perhaps they are due to error. There are multiple possible sources of error for our experiment. These include the weighing of the samples, incorrect amount of water used for each trial, errors when operating the thermometer, and inconsistent combustion of samples. One big source of error that we greatly reduced was the inconsistencies of the calorimeter. We did this by using benzoic acid to find the specific heat, then repeating this multiple times. To see if error affected our results, we need to test for statistical significance.

The results for the foods tested, minus Snickers, are backed up by P-values showing significance. These P-values happen to be very low, under 1%, for All Bran and Pringles, which are our two foods with measured Calorie counts over the label by more than 20%.

Although this data could support the hypothesis of Food companies manipulating the FDA mandated food label, the cause for these discrepancies could be a true unknowing error on the part of food corporations. To label food, the Atwater system is used. This system uses the macronutrient content of food and their related Calorie counts to these macronutrients. For example, if a 100g food contains 40% carbohydrates, and carbohydrates contain 4 Calories per gram, 160 Calories come from the carbohydrates. This is then totaled up for all the macronutrients. This system uses estimations and, for certain types of foods like almonds, it has been shown to be not as effective or accurate as predicted (Novotney, et al. 2012).

In the first case, this is a malicious use of the error margin to deceive consumers, while the second is an honest problem with the current methods. Either way, this pattern of error gives reason for a review of the current allowances and methods used. This is important because the first two tips on Health.gov for how to use a food label both relate to Calorie counts, showing how vital getting this number correct is (Tips for using the food label, n.d.).

Similar studies have been performed as well in respect to the validity of food labels. One particular study noted a discrepancy in the Calorie counts reported in food labels as well (Urban et al., 2010). Yet, they focused on different aspects, such as undervalued Calorie counts in other places rather than food labels, such as restaurants. All of these experiments, including our own, could help individuals who are trying to regulate their weight by counting their daily Calorie intake by making them more aware and skeptical about the Calorie counts of certain products, brands, or places. They could also help the FDA and big companies implement additional measures and requirements to try to minimize these problems concerning Calorie counts.

Overall, this data is enough to suggest that FDA regulated Calorie counts are inaccurate. While error is always a factor, the magnitude and P-value of the difference between measured and labeled calorie counts is too large to be a mistake. Motivations for mislabeling calorie counts could include making food products more appealing, but this mislabeling might even be a mistake because of outdated Calorie counting systems. Either way, how calorie counts are labeled needs to be revisited and revised.

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Lead Member: All

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In addition, except for the materials & methods image, all of the pictures and diagrams were obtained from Google Images.

Responsibilities

Lead Member: All

The abstract was written and edited by [redacted]. The introduction was written and edited by [redacted]. The materials & methods section was written [redacted] and edited by [redacted]. The results were mainly written by [redacted] with the T-test and problems-encountered portions written by [redacted]. The discussion was written by everybody. The references were written by everybody as well. Finding the articles, as well as writing and citing information from them was done by all. We all researched for scientific journals. In like manner, even though only one member focused on editing each section, for the most part, everybody contributed to the writing of each section.